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Development of a Sustainable 3D Printing Maintenance Management Model for Educational Aviation Facilities: A Case Study at WCC Aeronautical & Technological College – North Manila

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Abstract **- The aviation training field's under growing pressure to weave eco-friendly practices into how it teaches. This study aims to build a green maintenance plan for WCC Aeronautical & Technological College – North Manila, helping it use resources smarter, cut down on trash, while lifting its environmental game. AMT courses involve fixing planes, spotting problems, doing routine checks - activities that leave behind dangerous waste along with regular junk, including old oil, filters, plastic bits, scrap metal. Without solid handling, such waste may damage nature and mess up daily operations. The proposed approach uses eco-friendly techniques by combining 3D printing with physical models, allowing safe and precise testing of maintenance tasks while cutting down on material waste. Information will come from watching procedures, surveys, or talking directly with staff - this helps spot current flaws in upkeep and green practices. SMMM stresses early repairs, separating trash properly, tracking maintenance logs, plus meeting environmental rules set by regional and international bodies. Putting this model into action should boost performance efficiency, ensure laws are followed, also improve safety in learning environments. This research supports better long-term management of aviation training facilities, pushing schools toward smarter growth and stronger care for the planet.**

Keywords: ***Sustainable Maintenance Management, Aviation Education, Environmental Sustainability, 3D Printing, Waste Management, Operational Efficiency***

I. THE PROBLEM AND ITS BACKGOUND INTRODUCTION

1.1 Background of the Study

Aviation upkeep courses need practical exercises so learners build solid know-how; yet standard teaching tends to involve oils, substances, and real plane components that leave behind trash while raising health and ecological concerns. Over at WCC Aeronautical & Technological College – North Manila, routine practice sessions plus simulated repair jobs result in multiple kinds of leftover material, whereas weak record-keeping, poor sorting of refuse, and spotty tracking might cause disorganization or danger.

To tackle these issues, quite a few up-to-date flight academies are shifting toward eco-friendly tech like 3D printing. Instead of traditional methods, additive fabrication helps teachers build mock-ups of planes

Parts plus practice tools made without actual devices or disposable supplies. That cuts down trash, saves money, while keeping learners out of harm's way. Off the teaching side, printed objects help fix buildings - think durable tags, handy gadgets, storage helpers, little things that make work smoother.

Creating a green 3D printing upkeep system gives WCC Aeronautical & Technological College – North Manila a clear method to blend eco-conscious habits into flight tech courses. Instead of just using new materials, they could monitor usage, reuse leftover

filaments, or shift to online stock logs - so things run safer while cutting down waste. With these steps, the school upgrades how it works without harming nature. That fits right into learning wisely and servicing gear thoughtfully, swapping old routines for smarter choices.

1.2 Objective of the Study

General Objective

This research aims to build a practical Maintenance Management Plan for WCC Aeronautical & Technological College - one that supports eco-friendly upkeep strategies along with modern tools like 3D printing and scaled-down models. It highlights how flight training centers must shift toward greener maintenance routines without compromising safety or precision.

This research focuses on:

1. Check how things are maintained right now at WCC Aeronautical & Technological College – North Manila, along with lab routines - spot where waste builds up or resources get used too much.
2. Set up a clear system to handle waste sorting, eco-friendly cleaning routines, WHILE boosting how resources are used effectively.
3. Use 3D printing along with small-scale models in lab work so less material gets tossed out while also making practice gear easier to reuse.
4. Create green rules plus practical checklists that match CAAP, DENR, or DOTr requirements so offices stay on track legally.
5. Evaluate how the new model helps in teaching and day-to-day running, looking at whether it improves learning standards, upkeep of buildings, or reduces environmental harm.

1.3 Significance of the Study

Students get a cleaner, safer space to learn since they're less exposed to risky stuff like chemicals or waste. Instead of using lots of disposable parts, they work with 3D-printed pieces and mini models - so real-world practice feels more doable. Because of this setup, learners start thinking green from day one, which helps them fit into today's eco-conscious aviation scene later on.

Faculty get a clearer way to handle repair items, keep track of resources, while disposing trash responsibly. Work areas become tidier, easier to use, plus teaching tools last longer. Instructors find it simpler to include eco-friendly ideas in AMT classes - lessons then match today's flight industry needs along with environmental shifts.

This model could lower everyday costs at the school, make gear last longer - while also meeting eco and flight safety rules. Shifting to 3D printing along with green practices might help WCC Aeronautical & Technological College – North Manila upgrade how it trains students, keep safer conditions around campus, yet stand out as a progressive hub for aviation learning.

This study adds value to aviation learning circles by sharing practical ideas - helping shape rules while nudging schools toward eco-friendly teaching tools. Since the approach fits worldwide green targets, it pushes training programs to act smarter and plan ahead, blending new methods with real-world planet protection.

II. METHODOLOGY

2.1 Research Design

This research uses a descriptive, qualitative setup along with hands-on action methods. It focuses on careful watching, recording, details, yet includes real-world testing to build a Sustainable Maintenance Management Model made for WCC Aeronautical & Technological College – North Manila. Instead of just theory, it blends interview insights, survey results, field notes while applying them directly - making sure the model works in practice. Although rooted in real feedback from staff, site visits, discussions, the approach keeps testing adjustments so outcomes stay practical, grounded, useful.

This study uses a case approach centered on WCC Aeronautical & Technological College – North Manila to explore real-world maintenance routines,

how waste is handled, or potential green upgrades. By testing hands-on solutions like mini physical prototypes, 3D printing trials, or step-by-step maintenance plans, it shapes and improves new methods through direct feedback.

2.2 Population and Sample of the Study

The study includes teachers, support staff, plus learners actively taking part in the Aircraft Maintenance Tech program at WCC Aeronautical & Technological College – North Manila. These people count as key players since they handle real repair tasks, oversee gear and tools, also add to trash output while practicing skills.

To keep things practical while still meaningful, we picked participants carefully based on these traits:

1. Folks on staff handling AMT lab sessions, whether they're showing students the ropes or running experiments.
2. Maintenance crew handles equipment care, along with tools, while keeping training areas in working order.
3. AMT students during last year, while working directly on plane repairs.

A group of 50 people took part in the research – 10 department heads, 20 faculty teachers, alongside 20 upper-level students. The mix gives varied views about upkeep routines, how trash gets managed, or opportunities for eco-friendly changes.

2.3 Research Instruments

To collect thorough information, this study used several tools - like surveys, interviews, or observations - depending on what fit best at each stage

1. Observation Checklist
- Folks wrote down how stuff was maintained, got rid of trash following set routines, while keeping lab work ticking along step by step.
- Watched daily work to spot problems, while checking for dangers that could hurt people or harm nature.

2. Survey Questionnaire
- A set of clear questions was given to people to check their views, knowledge, and habits around eco-friendly practices, upkeep strategies, along with use of 3D printing tech.
- The survey had Likert-style items, multiple choice options, yet also open questions - to get both number-based results alongside deeper responses.

3. Document Review
- Finding old files, checking repair notes, or looking through rule documents helped confirm what people said alongside what we saw.
- This made it easier to spot weaknesses in tracking data, distributing supplies, or following eco rules.

4. Prototype Testing Records
- During design and build stages, 3D-printed versions along with smaller test models helped mimic repair work.
- Detailed logs tracked material use, how well tasks were done, time spent, along with safety results - all to check whether the suggested approaches actually work over time.

2.4 Data Collection Procedure

The data gathering for this study happened across three key stages to get a full picture of how things work now - and whether a Sustainable Maintenance Management Model could actually run at WCC Aeronautical & Technological College – North Manila. During stage one, an initial check was done using organized observations, questionnaires, alongside talks with people - to map out how maintenance is handled, how waste gets managed, plus how aware staff, faculty, and learners are about environmental issues. That round helped spot weak spots, safety concerns, as well as missing efforts toward greener methods. Stage two zeroed in on building the SMMM then putting it through real-world tests. First info from early checks helped build hands-on tools - like mini models made with 3D printing - that copied repair jobs in a lab setup. These real-world trials were watched closely to check how precise they were, how fast tasks got done, how much material was used, and just how much trash they cut down. Then came step three - testing and tweaking

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the model one more time. What trainees said, along with numbers gathered during tests, was looked at closely so changes could be made to make everything work better, fit real-world needs, leave less environmental impact, and actually teach well. Doing things this way created a strong starting point for building a hands-on system - eco-smart and built for maintenance training at flight schools.

2.5 Statistical Treatment

Data gathered through surveys plus field notes got broken down with basic number summaries - counts, averages, or how often things showed up - helping spot what upkeep steps folks use along with their grasp of eco-friendly habits. Interview answers were sorted by common ideas instead, pulling out key hurdles or openings for greener approaches. To keep score readings simple, a rank system was applied for clearer sense-making.

Mean Range	Description
4.20 – 5.00	Excellent
3.40 – 4.19	Very Satisfactory
2.60 – 3.39	Satisfactory
1.80 – 2.59	Fair
1.00 – 1.79	Poor

III. RESULTS AND DISCUSSION

This part of the research presents how the collected information was examined and understood based on responses from participants.

3.1 Profile of Respondents

A total of 50 people took part in the survey - 10 were Department Heads (20%), while 20 were Faculty Members (40%) and another 20 came from Aircraft Maintenance Technology (AMT) students (40%). Because roles varied, viewpoints from leadership, teaching, or practical learning were included. This mix helped cover key areas across administration, education, and technical training without leaving major gaps.

Respondent Group	Frequency	Percentage
Department Heads	10	20%
Faculty Members	20	40%
AMT Student	20	40%
Total	50	100%

3.2 Assessment of Current Maintenance and Laboratory Practices

Indicator	Mean	Description
Documentation and consistency of maintenance procedures	3.42	Very Satisfactory
Control of unnecessary waste generation	3.18	Satisfactory
Monitoring of energy and water usage	3.07	Satisfactory
Regular evaluation of maintenance efficiency	3.25	Satisfactory
Overall Mean	3.23	Satisfactory

Interpretation:

Looking at the findings, today's laboratory work and upkeep routines mostly do what they should. Still, keeping track of supplies and spotting trash could be better. A clearer plan for care might help, one that pays closer attention to long-term use and cleanup. Not everything fits perfectly now.

3.3 Waste Segregation and Eco-Friendly Resource Management System

Indicator	Mean	Description
Availability of labeled waste segregation bins	3.85	Very Satisfactory
Awareness of eco-friendly cleaning procedures	3.60	Very Satisfactory
Use of environmentally safe cleaning materials	3.55	Very Satisfactory
Efficient use of utilities and consumables	3.40	Satisfactory
Overall Mean	3.60	Very Satisfactory

Interpretation:

Sorting trash properly along with green habits works well here, proving the place gets what sustainability

means. Still, using resources more wisely would help things even more.

3.4 Integration of 3D Printing and Reusable Training Models

Indicator	Mean	Description
Reduction of material waste through 3D printing	4.10	Very Satisfactory
Effectiveness of reusable models in instruction	4.25	Excellent
Improvement of learning through reusable equipment	4.30	Excellent
Reduction of disposable training materials	4.05	Very Satisfactory
Overall Mean	4.18	Very Satisfactory

Interpretation:

What stands out is how well 3D printing works alongside reusable templates - feedback was clearly favorable. Learners grasp concepts better because of them, yet consumption drops sharply. This shift lines up naturally with long-term educational sustainability.

3.5 Compliance-Based Green Policies and Operational Checklists

Indicator	Mean	Description
Alignment with CAAP, DENR, and DOTr regulations	3.71	Very Satisfactory
Awareness of environmental compliance requirements	3.55	Very Satisfactory
Effectiveness of operational checklists	3.80	Very Satisfactory
Conduct of audits and compliance inspections	3.45	Very Satisfactory
Overall Mean	3.63	Very Satisfactory

Interpretation:

Survey results show that green policies and compliance mechanisms are very satisfactory, particularly in terms of alignment with regulatory agencies. Regular audits, however, may still be strengthened.

3.6 Evaluation of Educational, Operational, and Environmental Impact.

Indicator	Mean	Description
Improvement in teaching and learning quality	4.20	Excellent
Improvement in facility maintenance	3.90	Very Satisfactory
Reduction of environmental impact	4.05	Very Satisfactory
Improvement in overall operational efficiency	3.95	Very Satisfactory
Overall Mean	4.03	Very Satisfactory

Interpretation:

The implementation of the proposed SOPs has a very satisfactory to excellent impact on instruction, operations, and environmental sustainability, indicating that the model is both effective and beneficial.

3.7 Overall Survey Summary.

Indicator	Mean	Description
Assessment of Current Maintenance and Laboratory Practices	3.23	Statisfactory
Impr Waste Segregation and Eco-Friendly Resource Management System maintenance	3.60	Very Satisfactory
Integration of 3D Printing and Reusable Training Models	4.18	Very Satisfactory
Compliance-Based Green Policies and Operational	3.63	Very Satisfactory

Checklists		
Evaluation of Educational, Operational, and Environmental Impact	4.03	Very Satisfactory
Overall Mean	3.73	Very Satisfactory

Interpretation:

Looking at everything together, the outcome shows a high level of satisfaction with the new sustainability plan for labs and upkeep at WCC Aeonautical & Technological College – North Manila. What stands out is how well it brings together modern tools, adherence to ecological standards, yet still supports strong teaching outcomes.

IV. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

4.1 Summary of Survey Findings

A fresh approach took shape here - focusing on maintenance for 3D printers within aviation education settings. WCC Aeronautical & Technological College – North Manila became the real-world test site. Waste buildup had been piling up during standard AMT classes, drawing attention. Resources were slipping through gaps in daily operations. Environmental hazards quietly grew alongside routine exercises. This model stepped in - not as a fix-all - but as a structured shift. Each part of upkeep got rethought from first touch to final check. Learning spaces began reflecting long-term thinking instead of quick results. Tools changed hands with purpose, not habit. Surfaces stayed cleaner because steps followed logic, not rush. Materials lasted longer when handled with clear rules. Mistakes dropped once routines settled into place. Training now leaves less behind after class ends. Thought went into timing, spacing, tool paths - all woven together without noise. Progress shows not in speed but in consistency. Small changes added weight over weeks. Old flaws lost power when new patterns held firm. Attention turned outward - to air, to runoff, to storage yards. Responsibility spread across roles that once worked alone.

A close look at real-world situations shaped how information was gathered, relying on clear observation methods alongside surveys and talks with people involved. Instead of just numbers, stories came from records checked by hand plus feedback during early model trials. People leading departments joined conversations, along with teachers and advanced tech learners who shared experiences about upkeep routines. Their thoughts covered rules they follow, handling trash responsibly, and whether using 3D printers actually helps teach better. Each voice added depth to understanding current habits within the system.

Feedback showed upkeep and lab routines meet expectations, though room exists to track trash and supplies more closely. Notable progress stands out where sorting rubbish began, along with greener ways to clean - both seen as working well. Teaching tools made through 3D methods, built to last past one use, earned top marks across reviews. These approaches cut down excess materials while sharpening how students engage during practice sessions. Rules tied to environment standards set by CAAP, DENR, and DOTr are followed carefully, a sign operation stay within required frameworks.

What stands out is how clearly the results support SMMM's role in lifting education standards while streamlining daily operations. Facility upkeep sees noticeable improvement under this model, not just in function but in lasting impact. Environmental care becomes built-in, not an afterthought. For flight schools aiming to grow without burning out resources, this approach fits well into real-world needs.

4.2 Conclusions from the Survey

From the survey results alone, it appears that:

1. Fine now, yet gaps linger where oversight should tighten around trash flow. Tracking tools? They exist - just not always used right. Watch how supplies move through departments; patterns show room to grow. Preventive checks happen, sure, though timing often feels more random than routine. Systems hum

along without breaking down, still far from polished under close look.

2. Starting with clean sorting of trash, labs begin to lighten their footprint on nature. When materials get handled with care, less harm slips through the cracks. One step at a time, small choices add up - bottles reused, bins separated, energy saved. Responsibility grows quietly where habits shift without fanfare. Operations run smoother when Earth isn't an afterthought.

3. Starting fresh each time, 3D printing combined with repeatable training tools cuts down on wasted materials. Learning gets better when practice setups stay consistent. Safety improves because conditions are predictable. For students in AMT programs, control matters - mistakes happen less often when surroundings do not change.

4. Built on rules, green practices take shape through clear routines that match what CAAP, DENR, and DOTr require. These steps hold institutions responsible while staying within legal lines. By following structured paths, teams meet environmental goals without guesswork. Each checklist acts like a steady guide under real-world conditions. Alignment grows naturally when procedures are repeated with care. Legal safety comes not from promises but consistent actions. What matters most shows up in daily choices, not grand plans.

5. A fresh look at how things run shows better teaching, smoother operations, cared-for buildings, cleaner surroundings. This approach fits well where flight training happens. Its value stands clear through real results.

4.3 Recommendations Based on Survey Results

Based on the survey results, these suggestions are put forward:

1. Institutional Adoption of the SMMM

WCC Aeronautical & Technological College – North Manila should formally adopt the Sustainable Maintenance Management Model across all AMT laboratories and maintenance-related facilities.

2. Strengthening Preventive Maintenance and Monitoring Systems

The institution should implement digital maintenance logs, material tracking systems, and regular sustainability audits to enhance preventive maintenance and reduce resource wastage.

3. Expansion of 3D Printing Applications

Additional investment in 3D printing equipment and biodegradable or recyclable filament materials is recommended to expand reusable training tools and reduce dependency on disposable components.

4. Continuous Training and Capacity Building

Regular seminars and workshops should be conducted for faculty, staff, and students to reinforce environmental awareness, regulatory compliance, and sustainable maintenance practices.

5. Enhanced Compliance Evaluation

Periodic internal and external audits aligned with CAAP, DENR, and DOTr standards should be conducted to ensure consistent compliance and continuous improvement.

6. Future Research Directions

Further studies may examine long-term cost savings, environmental impact metrics, and student performance outcomes, as well as replicate the model in other aviation and technical training institutions.

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